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AUTHOR Miller, Patricia H.; And Others
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# THE ROLE OF STIMULUS DIMENSIONS IN THE CONSERVATION OF SUBSTANCE

Patricia H. Miller
Teddy L. Grabowski
and Karen H. Heldmeyer

University of Michigan

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Two studies examined how nonconservers use the dimensions relevant to quantity in the conservation of substance task. Most nonconservers are very selective in their use of the information provided by these dimensions. Most preschool and kindergarten nonconservers used length to define amount, while ignoring width. This was true regardless of how extreme the transformations were, in what order children saw the transformations, and whether the transformation was begun anew on each trial or continued from trial to trial. The youngest preschool children, however, were not as likely as the older preschoolers to restrict themselves to the length dimension. The results were interpreted as being counter to Piaget's four-step equilibration model of how compensation and conservation develop.

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Patricia H. Miller[2]
Teddy L. Grabowski
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University of Michigan

Several accounts of the development of conservation focus on how children reason about the physical dimensions involved. The best known example is Piaget's concern with compensation, the notion that the relevant dimensions (e.g., height and width) of a given quantity vary inversely. Piaget considers compensation a necessary, but not a sufficient, condition for conservation (Piaget, 1[illegible]).

Piaget describes how conservation develops in a four-step model based on an equilibration process (e.g., Piaget, 1960, 1967, 1970). In a test of conservation of substance, one of two identical balls of clay is transformed into an elongated sausage. Piaget describes a situation in which children are shown a series of transformations into successively longer and thinner sausage shapes. In Step 1, a nonconserver considers (centers on) only one dimension--length or width. If he centers on length he judges that the sausage has more clay than the ball. When the sausage is made longer and longer, the child switches to the dimension he did not center on in Step 1 (in this case, width). Consequently, he makes the opposite nonconservation error in Step 2 (e.g., the ball has more than the sausage). This shift may be due to two factors. First, the child may feel dissatisfaction with continually giving the same answer under changing perceptual conditions. Second, there is an increase in the perceptual contrast between the length and width as the sausage becomes longer and thinner; thus, the dimension which was ignored at first becomes salient. Step 2 may also include alternation between the two dimensions. In Step 3 he begins to discover the correlation between changes in the two dimensions and shifts his concern from static states alone to the transformation which leads from state to state. In Step 4 the understanding of compensation is perfected and the result (given the presence of other cognitive operations) is conservation. Piaget usually describes these steps as though they occur within the conservation experiment itself, but it is highly unlikely he actually means that compensation develops in this artificial situation (Flavell, 1963). In fact, he has also applied this four-step model to the development of other concepts, e.g.,

seriation, classification, object concept.

Although a number of studies have examined the role of compensation in conservation (e.g., Bruner, Olver & Greenfield, et al., 1966; Gelman & Weinberg, 1972; Larsen & Flavell, 1970), there is little research on the steps leading up to compensation. The two studies reported here attempt to fill this gap. The studies were stimulated by Piaget's four-step model, but are concerned more generally with how nonconservers use the information provided by the dimensions which are relevant to quantity.

Miller (in press) found that in a test of attention height was much more salient than width for kindergarten nonconservers. Even after a series of probes which were designed to redirect the child's attention to less salient dimensions, many children were unable to switch from the height to the width of the liquids. On a later test of conservation, these nonconservers based their nonconservation answers on the heights of the liquids. Thus, nonconservers used the height dimension at the expense of width in these conservation and conservation-like situations. Children's lack of concern with width raises a problem for Piaget's claim that centering on both dimensions and, eventually, understanding compensation are crucial for conservation. Under what conditions, if any, do nonconservers begin to take the width dimension into account when they are reasoning about quantity? If such conditions cannot be found, then the claim that compensation of two dimensions is a prerequisite for conservation becomes quite doubtful. That is, there should be some point at which children begin to reason about width as well as height, if they eventually will learn to use these dimensions in a compensating way. Several investigators already have questioned Piaget's claims concerning compensation (e.g., Gelman & Weinberg, 1972; Wallach, 1969).

The two studies reported here examine the aspects of the compensation notion discussed above by looking at children's use of the length and width dimensions in the conservation of substance task. In order to gain a clearer understanding of the role of stimulus dimensions, the studies vary stimulus factors which Piaget's four-step model suggests are important, e.g., how extreme the transformations are, the order in which the child sees the transformations. There were two questions. Do these stimulus factors influence whether a nonconserver attends to length or width or both? Do these stimulus factors influence whether a child demonstrates nonconservation or conservation? The studies include the situation described in Piaget's four-step model (in which the sausage becomes longer and longer) and

several variations of it.

## Experiment 1

### Method

#### Subjects

The 84 kindergarten children were from two middle to upper middle class schools in Dearborn, Michigan. Nearly all of the children were white. One additional child was rejected because he did not understand the term "same amount". The age range was 5-2 to 6-3 with a mean age of 5-8. Fourteen boys and 14 girls were randomly assigned to each of the three conditions.

#### Procedure

The children were tested individually in a small room at the school. A child was shown two identical balls of clay (2" in diameter) and questioned as to their equality. After the child agreed they were the same, one of the balls was rolled out into a sausage. The child was asked, "Do we still have the same amount of clay, or does one of us have more now?" After his answer, the experimenter asked, "Do I have just as much as you?" The child then was asked to give an explanation. If nonconservers were unable to do so, they were asked to indicate nonverbally the basis for their judgments (i.e., "Can you show me with your hands why this one has more clay?"). The sausage was then removed from view and replaced by a ball of clay.

This procedure was followed for all four trials. The only difference between the trials was in how long the sausage was. (To insure exactness, the table surface was inconspicuously marked at intervals of 4, 7, 12, and 24 inches). The three conditions differed in the order of presentation of the four trials. In one condition the sausage increased in length over the four trials (4, 7, 12, and 24 inches). In another condition children saw the reverse (24, 12, 7, and 4 inches), and in another condition saw a mixed order (7, 24, 4, 12, or 12, 4, 24, 7). The first condition approximates the procedure Piaget used in his description of the four steps to compensation. By comparing the first two conditions it is possible to separate two variables which were confounded in Piaget's procedure: the fact that a child was given several trials with similar problems and the particular

length of the transformation. By comparing the first two conditions with the third, one can determine whether seeing a continuous and gradual change in length of transformation is important, or whether merely seeing several transformations of varying length can cause a switch to another dimension.

Scoring

A child was classified as a conserver if he said the ball and sausage were equal on all four trials. All children who did this were able to give an adequate explanation on at least three of the four trials. Adequate explanations referred to compensation, reversibility, previous equality, no addition or subtraction of clay, and irrelevancy of the transformation. Nonconservers thought the ball and sausage were unequal on all trials. All other chilren were called transitional.

## Results

Since there were no significant sex differences, boys and girls were combined in all analyses. The three conditions were very similar in their numbers of nonconservers, transitional conservers, and conservers. A chi-square test of nonconservers vs. transitionals plus conservers in the three conditions was not significant ($\underline{X}^2=2.95$, $\underline{df}=2$, $\underline{p}>.05$). Thus, the order in which a child sees the various degrees of transformation does not affect whether he will be a conserver. When the conditions are combined, the proportions of nonconservers, transitional conservers and conservers are .65, .14, and .20.

The focus of this study is on nonconservers and transitional conservers. Among the nonconservers, 69% thought the sausage had more than the ball on all four trials, 11% always thought the ball had more and 20% thought the ball had more on some trials and the sausage had more on other trials. The children apparently were basing their answers on the length or width of the objects (e.g., the sausage has more because it is longer). Evidence for this is that one or the other of these dimensions was included in the subjects' explanations on 84% of the trials (68% verbally and 16% nonverbally). (On most of the other trials either the child was unable to give an explanation or his explanation was unclear.) Thus, the dimension of length is quite compelling for kindergarten children. The proportion of children using length on all trials did not differ among the three conditions ($\underline{X}^2=1.51$, $\underline{df}=2$, $\underline{p}>.05$).

The small number of children who did not give the same answer on all four

trials were affected by how extreme the transformations were. This group consisted of the 11 nonconservers who chose both the ball and the sausage and the 12 transitional conservers who, by definition, had some ball and/or sausage choices in addition to their conservation choices. The general finding was that a higher proportion of children chose the ball or professed conservation on the 4" trial than on the other trials. More specifically, there were significantly more children choosing the sausage on the 7" trial but not on the 4" trial than the reverse (binomial test, $p = .029$). The same comparison was significant for the 24" vs. 4" trials ($p = .019$) but not the 12" vs. 4" trials ($p = .363$).

## Experiment 2

The finding of the first study that responses to width or both height and width are uncommon in kindergarten nonconservers raised two further questions. First, would younger children be more likely than kindergarteners to use width? Second, is there a better way to emphasize the correlated change in length and width than the method of the first study? To accomplish this, the same sausage was rolled out further and further over the trials without ever replacing it with a new ball. Successive and gradual transformations on the same object should draw attention to the relationship between the length and width.

### Method

#### Subjects and Procedure

There were thirty children (12 boys and 18 girls) aged 3-8 to 5-8, with a mean age of 4-8. An additional four children were rejected because of inattention or failure to understand the necessary verbal terms. The day care center was predominantly lower-middle class, racially mixed, and located in Ann Arbor, Michigan. The children were randomly assigned to two conditions.

The procedure of the first experiment was modified for use with preschool children. Children were given verbal pretraining on the terms "same amount", "more", and "less". Each child was shown a paper maché ball (the standard) and three other paper maché balls, one larger, one the same, and one smaller. The child was asked which balls had the same amount, more, and less than the standard. Next, the same procedure was followed with four clear plastic bags of uncooked popcorn. Whenever a child did not give a correct answer, the experimenter tried to elicit the correct answer by using paired comparisons. If necessary, the basis

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for the correct answer was explained to the child. Then the experimenter repeated the original three questions about the amounts.

Next, four conservation of substance trials were presented in the same way as in Experiment 1. However, there were only two conditions. In one condition the sausage increased in length as in the first condition in Experiment 1. In another condition, each new trial did not begin with two equal balls of clay. Instead, there were two balls of clay to begin the first trial, but thereafter the same sausage was rolled out longer and longer over the four trials.

## Results

Since there were no significant sex differences, both sexes were combined in all analyses. Twenty-five children were nonconservers, 4 were transitional, and 1 was a conserver. The preschool nonconservers were very similar to the kindergarten nonconservers in their performance. Seventy-six per cent thought the sausage had more than the ball on all four trials, 4% thought the ball had more, and 20% were mixed (the corresponding percentages for the kindergarteners were 69, 11, and 20). The two conditions were almost identical in the proportions of children giving these three patterns of response. Another finding was that the percentages of children choosing the sausage rather than the ball on the 4, 7, 12, and 24 inch trials were similar--76, 86, 82, and 86.

There was a significant age trend (median split, Fisher's Exact Test, $p=.033$). Older children were more likely than the younger to choose the sausage on all four trials. Table 1 indicates that this difference was primarily due to the fact that the very youngest children did not tend to choose the sausage on all trials. When the kindergarteners from the first study are included, there appears to be a curvilinear relationship between age and type of response. Of the 29 kindergarteners in the "other" category, six chose the ball, 11 chose both the ball and the sausage, and 12 were transitional conservers.

Because of the small number of transitional conservers who gave two or more nonconservation answers, their data from both studies must be combined for any statistical tests. Four transitional conservers chose the sausage exclusively in their nonconservation answers and eight gave other answers (the ball exclusively or a mixture of the two); the comparable numbers for nonconservers were 57 and 23 ($\chi^2=5.12$, $df=1$, $p<.05$). Thus, despite the fact that the transitional conservers had only two or three nonconservation trials in which they could choose the ball

(in comparison to four trials for the nonconservers), they were more likely to choose the ball or both the ball and the sausage than were the nonconservers.

## Discussion

Most nonconservers are very selective in their use of information provided by the stimulus dimensions in the conservation task. They think that length properly defines amount. They maintain this belief over several problems regardless of how extreme the transformation is, in what order they see the transformations, or whether the transformation is begun anew on each trial. The results are similar to those of Miller (in press) who found that most nonconservers use height as a measure of liquid quantity. Thus, length or height is considered to be relevant, while width or fatness is not.

There are two possible explanations for the dominance of length; one is attentional and the other cognitive. Length may be more perceptually salient than width. In absolute terms, the length changes much more than does the width when the ball is rolled out into a sausage. Therefore, the child may not even notice that the sausage is becoming skinnier. He then reasons that since the length is increasing, the amount must also be increasing.

An alternative explanation emphasizes the child's growing understanding of the world. In his past experience the child may have noticed that long things often have more than shorter things. For example, a stick of candy has less and less as it is eaten and becomes shorter. If a crayon breaks, each broken piece has less than an unbroken crayon. Length is, in fact, a fairly reliable indicator of amount. The fact that the younger preschool children did not rely on length as much as the older preschool children suggests that using length to estimate amount may be a positive developmental acquisition. This strategy may require more experience with objects than the younger children have had. Pufall and Shaw (1972) recently reported a similar developmental trend. In a series of conservation-like number problems, 2-year-olds sometimes based their judgments on length and sometimes on density, while 4- and 5-year-olds predominantly used length.

The present studies indicate that Piaget's four-step model should be modified. His four steps involved centering on one dimension, centering on the other dimension, using both dimensions successively and then simultaneously, and finally compensation of dimensions and conservation. Both intra-subject and inter-age data differed from that expected on the basis of this model. Seeing the sausage become longer

over several trials caused very few children to switch to another dimension. Furthermore, the fact that most nonconservers used length suggests that if all children have a period of time when they attend to width and a time when they alternate between width and length, these periods evidently are very brief. Furthermore, the developmental trend was opposite to that hypothesized by Piaget. It was the youngest children (as well as the oldest children) who were less likely than the other children to use length exclusively. This age trend should, of course, be replicated with a larger number of subjects.

In partial support of Piaget's model is the fact that the transitional conservers were less likely than the nonconservers to use length on all the trials in which they gave a nonconservation answer. This indicates that children who are very close to being conservers have broken away from the restricted use of dimensions which characterizes nonconservers.

Future research might determine whether the nonconservers who switch from one dimension to another are closer to becoming conservers than those children of the same age who choose only one dimension. Another important question is to what extent, if at all, width is noticed by the children who base their answers on length exclusively. Eye movement photography and measures of incidental recall might help answer this question.

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NUMBERED FOOTNOTES

1. Experiment 1 is based on the second author's senior honors thesis at the University of Michigan. Experiment 2 was supported by a University of Michigan Rackham Faculty Research Grant to the first author. The authors are grateful to Perry Nursery School in Ann Arbor, Michigan, and the Clark and Haigh elementary schools in Dearborn, Michigan, who participated in this research.

2. Requests for reprints should be sent to Patricia H. Miller, Department of Psychology, University of Michigan, Ann Arbor, Michigan 48104.

Table 1

Age Trends in Patterns of Response Among Nonconservers and Transitional Conservers

| Age | Sausage[a] Has More | Other[b] |
|---|---|---|
| Preschool | | |
| 3-8 to 4-3 | 1 | 6 |
| 4-5 to 4-7 | 6 | 2 |
| 4-8 to 5-1 | 5 | 2 |
| 5-2 to 5-8 | 7 | 0 |
| Kindergarten | 38 | 29 |

Note. -- The preschool Ss were divided into age quartiles.

[a]The sausage was chosen on all four trials.

[b]Always chose ball, sometimes chose ball and sometimes sausage, or a mixture of nonconservation and conservation.